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A MOBILE UNIT FOR AUTOMATIC COLLECTION OF COMPUTER-COMPATIBLE MACROCLIMATIC AND MICROCLIMATIC FIELD DATA

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A MOBILE UNIT FOR AUTOMATIC COLLECTION OF COMPUTER-COMPATIBLE MACROCLIMATIC AND MICROCLIMATIC FIELD DATA

By J. W. Smith, E. A. Stadelbacher, and C. W. Gantt[1]

ABSTRACT

A mobile unit for the automatic collection of weather data for use in conjunction with field experiments was designed and assembled. The system eliminates the need for the manual reduction, analysis, and accumulation of weather data, for it is computer-compatible. The unit consists of environmental sensors, signal translators, a data integrator, a data logger, and a paper-tape punch, all housed in a specially designed trailer. A pyranometer, an anemometer, a wind-direction transmitter, a rain gage, an ambient-temperature sensor, and a dewpoint sensor are mounted on a rack on top of the trailer for the collection of data in the field. Other temperature and dewpoint sensors are placed away from the trailer among the crops. Computer programs were developed to process the data. Except for a few problems—interruption of power in remote areas, dust, and sensitivity of punch recorder to high humidity—the system has operated satisfactorily.
KEY WORDS: automatic collection of weather data, collection of climatic field data, macroclimate, microclimate, weather.

INTRODUCTION

Climatic factors produce many effects on agroecosystems. Insects in particular are sensitive to temperature, humidity, and barometric pressure, all of which directly affect developmental rates and behavior. Other factors such as rainfall, solar radiation, and wind speed also affect insects, other arthropods, and plants, in extremes killing these organisms. Agricultural researchers realize that weather conditions may enhance or negate pest-management practices, for example, the reduction of insecticide effectiveness because of rainfall. The design of pest-management systems must account for weather variations.

Research involving the measure and recording of the physical environment of crop ecosystems has been severely limited by the time required to reduce and analyze the data manually. The ecological research team at the Bioenvironmental Insect Control Laboratory at Stoneville, Miss., has designed and assembled an automatic unit with computer-compatible outputs for the collection of weather data.

METHODS AND MATERIALS

Instrumentation

Figure 1 shows the instrumentation used in this system and illustrates the relationship of the various parts: environmental sensors, signal translators, a data integrator, a data logger, and a paper-tape punch.

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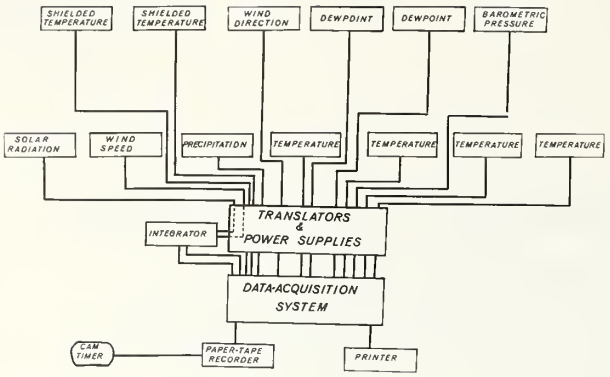

FIGURE 1.—Relation of parts and instrumentation employed in unit.

Sensors

Temperature.—Temperature is measured with thermistors that produce a linear resistance change with temperatures between —10° to 110° F. The resistance output is converted to an electrical analog signal. In unit 6, thermistors measure temperatures at two depths in the soil, two levels within the plant canopy, and two positions in the ambient air. The latter two thermistors are shielded, and a blower housed in the shield keeps a constant airstream passing over the thermistor. The shield reduces error, caused by radiation, in the measurement of air temperature to a maximum of ±0.2° F.

Dewpoint.—The dew cell is a lithium chloride type mounted in the bottom part of the ambient-temperature shield. The dewpoint-sensing element is a thin-walled metal socket covered with a woven-glass tape and wrapped with a gold-wire circuit supplied with 24 V a.c. The woven glass is impregnated with a lithium chloride solution. At an equilibrium temperature the solution neither absorbs nor gives up moisture to the atmosphere. Below the equilibrium temperature, the salt solution absorbs moisture, and above it, the saturated salt solution looses moisture until only dry crystals remain. If the element is below the equilibrium temperature, the conductivity of the solution on the tape becomes greater, increasing the current flow, in turn raising the temperature of the element to equilibrium. This temperature is then converted to an electrical analog signal that is used as a measure of dewpoint.

Barometric pressure.—The pressure transducer produces a resistance output proportional to atmospheric pressure. The sensing element consists of five stacked diaphragms of NiSpan-C alloy housed in a weatherproof enclosure. The diaphragms, which expand and contract with changes in pressure, are mechanically linked by Invar fittings to a potentiometer. The variable resistance output of the pressure sensor is converted to an electrical analog signal for reading of atmospheric pressure in the 28 to 32 inHg range.

Solar radiation.—Total sky radiation is measured by an Epply-type pyranometer. The detector is a radial wire wound on a differential thermopile with the hot-junction receivers blackened and the cold-junction receivers whitened. When the sensor is exposed to solar radiation, the black and white surfaces develop a temperature difference that is converted to an electrical analog signal proportional to the intensity of the solar radiation.

Wind speed.—A 3-cup anemometer calibrated from zero to 100 mi/h measures wind speed. Cup movement actuates a sealed magnetic-reed switch by means of a magnet attached to the sensor shaft. Output signals are a series of contact closures at a frequency proportional to wind speed.

Wind direction.—Wind direction is measured by an airfoil vane coupled to a microtorque potentiometer that provides tracking of wind-direction variations. Wind direction is filtered with a time constant of 15 seconds to provide a smooth trace. The output signal is a continuous d.c. voltage directly proportional to wind direction from 0° to 359°.

Precipitation.—A weighing rain gage measures precipitation. An 8-in collector ring directs rainfall into a bucket housed within the gage. The catch bucket has a 12-qt capacity, the equivalent of 12 in of rainfall. Collected rain is measured in terms of weight, with 1 in of rainfall at 62.56° F equivalent to 29.02 oz. The scale supporting the catch bucket is connected to the shaft of a potentiometer that produces an electrical analog signal directly proportional to the accumulated rainfall.

Translators

Signals from sensors are channeled into translators that are a variety of signal-conditioning printed-circuit boards housed in a common instrument rack. A self-contained power supply energizes the circuit boards and those sensors requiring power. The circuit

boards convert the sensor signals to a linear voltage in the 0- to 100-mV range.

Integrator

An integrator is used for those parameters that may not represent the average situation, if instantaneous analog values are measured hourly. The two parameters accumulated are solar radiation and wind speed. The digitized data recorded for each integrated analog channel is an accumulation of all input values over a selected period of time. Such a collection permits the determination of cumulative effects and averages. Integrated intervals of 15, 30, or 60 minutes are switch selectable.

Data-Acquisition System

Data scanner

The output signals from each sensor, after leaving the translator in a 0- to 100-mV form, enter a 20-channel data-acquisition system (Esterline Angus model D2020). The unit, a digital d.c.-mV measuring device, scans channels at preselected intervals, provides a visual digital display and a digital printout, and gives input to a recording device. The system also incorporates a 24-hour digital clock and a 365-day dating device that identifies all data. This unit is completely solid state, and most of the circuit functions are on printed-circuit boards.

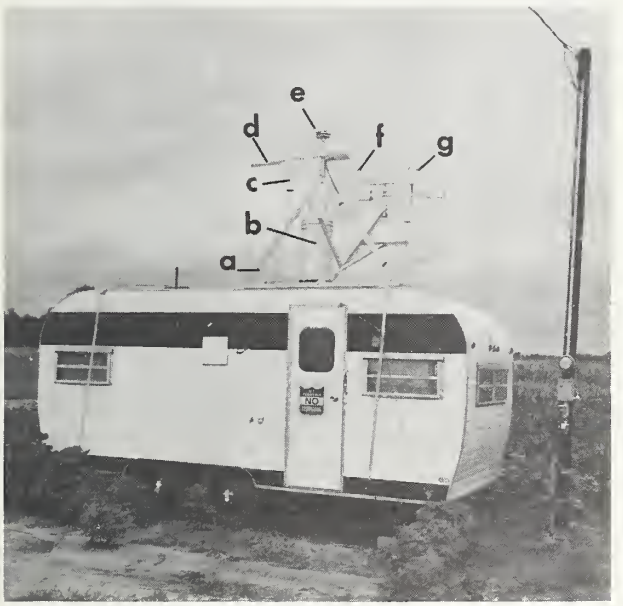

FIGURE 2.—Trailer with sensors on top rack: a, folding aluminum sensor rack; b, rain gage; c, dewpoint sensor; d, shielded ambient-temperature sensor; e, pyranometer; f, wind-direction transmitter; g, anemometer.

Paper-tape recorder

The data-acquisition system is interfaced with paper-tape perforator (Tally model P–120) and a driver amplifier (Tally model PD–120). Digital data punched on the paper tape can be fed into a tape reader and entered directly into a computer. To avoid continuous operation of the paper-tape perforator, a cam timer activates the perforator and its driver, which is programed to record data. When hourly data are being collected, the perforator is turned on by the timer 1 minute prior to punching for proper warmup.

Mobile Unit

Instrument housing

An 18-ft tandem-wheel trailer specially designed to house, protect, and transport the data-acquisition system is shown in figure 2. The data unit is housed in a 4-ft standard in-

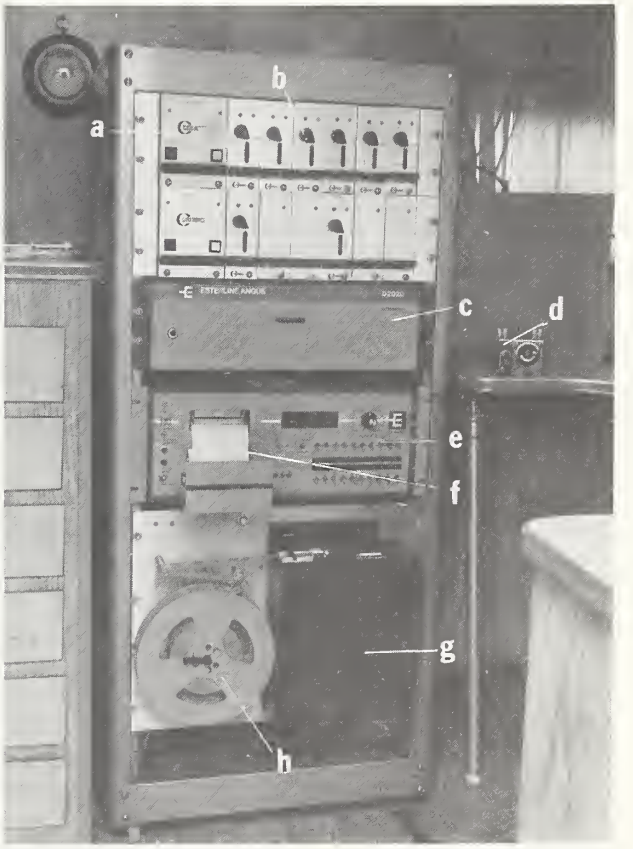

FIGURE 3.—Instrument console: a, translator power supply; b, removable printed-circuit boards of translators; c, integrator; d, cam timer for punch; e, data-acquisition system; f, digital printer; g, paper punch recorder; h, paper-tape-storage reel.

strument console, which is on rollers for easy movement and access to interfacings in the rear. Figure 3 shows the console with electronic equipment in place. Instruments are powered by 110 V a.c. on a line separate from the air conditioner. The interior of the trailer is arranged to serve also as a field laboratory. The trailer is 6 ft wide and has an interior height of 6 ft 2 in. A 5,000-Btu window air conditioner provides an even temperature for the operation of the instruments and also filters dust from ventilation air.

Field setup

The trailer can be placed within or along the side of a study area. An aluminum instrument rack mounted on top of the trailer was fitted to hold the pyranometer, anemometer, wind-direction transmitter, ambient-temperature sensor, rain gage, and dewpoint sensor. These sensors can be disconnected and the rack folded flat on top of the trailer for unit relocation. Other sensors for the collection of field data can be placed away from the trailer, because connecting cables are 100 ft long.

Soil temperatures are measured with thermistors that are sealed to prevent the entrance of moisture. Both aspirated and unaspirated temperature sensors are used for measuring conditions in the crop. An aspirated, shielded sensor measures the ambient temperature at plant terminal height because of the potential radiation effect at this level. Thermistors within the crop canopy are not aspirated but are shielded with aluminum to avoid the detrimental effects of direct exposure to the sun. Dewpoint in the crop canopy is measured by placing the dew cell below the ambient temperature sensor in the crop canopy. All sensors in and above the crop canopy are adjustable to allow for crop growth (fig. 4).

A typical field setup used in cotton at Stoneville, Miss., is: (1) pyranometer, over trailer 10 ft above ground, (2) anemometer, over trailer 10 ft above ground, (3) wind-direction transmitter, over trailer 10 ft above ground, (4) ambient-temperature sensor, over trailer 10 ft above ground, (5) dewpoint sensor, over trailer 10 ft above ground, (6) rain gage, over trailer 8 ft above ground, (7) two temperature sensors, in plant canopy, (8) ambient-temperature sensor, at plant terminal height, (9) dewpoint sensor, in plant canopy, (10) soil-temperature sensor, at 2 in below soil surface, and (11) soil-temperature sensor, at 4 in below soil surface.

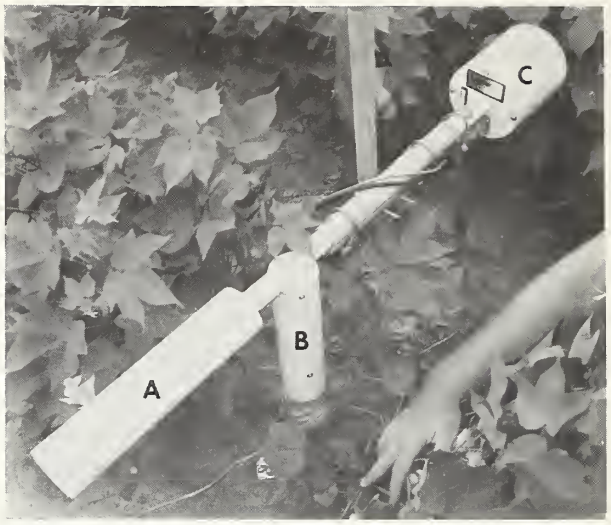

FIGURE 4.—Temperature shield and dewpoint sensor in cotton. *A*, Temperature shield (thermistor inside); *B*, housing for dewpoint shield (sensor inside); *C*, blower for airstream.

Computer Data Handling

Data are read into a Univac 1106 computer in the following form using ASCII code, a seven-bit code used extensively in various communications and data-processing systems.

Date ..... in Julian calendar.
Time ..... in 24-hour clock.

Channel
- 0 ..... temperature in °F.
- 1 ..... temperature in °F.
- 2 ..... temperature in °F.
- 3 ..... temperature in °F.
- 4 ..... temperature in °F.
- 5 ..... temperature in °F.
- 6 ..... dewpoint in °F.
- 7 ..... dewpoint in °F.
- 8 ..... barometric pressure in inHg.
- 9 ..... solar radiation in langleys.
- 10 ..... wind speed in mi/h.
- 11 ..... wind direction in degrees.
- 12 ..... rainfall in inches.

Blank line
Date
Time
Channel
- 0
- 1
- 2
- :
- :

Storage file

Data are placed in a storage file in the com-

puter with one complete set of data being recorded for each hour by a FORTRAN program, WTHR. SETUP. This program also changes hour 00 of any given day to hour 24 of the preceding day and rounds off minutes, if present, to the nearest hour.

The data record after execution of WTHR. SETUP is:

Columns	*Item*	*Format*
1–3	Day	I–3
4–5	Hour	I–2
6–10	—4-in temperature	F5.1
11–15	10-ft temperature	F5.1
16–20	Terminal temperature	F5.1
21–25	—2-in temperature	F5.1
26–30	Canopy temperature	F5.1
31–35	Plant temperature	F5.1
36–40	Dewpoint	F5.1
41–45	Barometric pressure	F5.1
46–50	Solar radiation	F5.1
51–55	Wind speed	F5.1
56–60	Wind direction	F5.1
61–65	Rainfall	F5.1

To convert the data to a preferred unit of measurement another FORTRAN program, WTHR.CNVRT, is used: (1) Rainfall of the previous hour is subtracted from rainfall of the succeeding hour to obtain rainfall during a given hour. If the results are negative, then rainfall will be zero. (2) Barometric pressure is calculated in inHg by the following formula: BRMT.PRS=28+0.04×(millivolts). (3) Wind direction is converted by following formula: WD.DRTN=4.5(millivolts). (4) Temperatures are calculated by subtracting 7.8 from millivolt readings. FORTRAN program WTHR.LST lists and labels the data and computes the averages of each of the parameters per day.

Plotting data

WTHR.GLDPLT is a FORTRAN program written to plot data on a Gould 4800 plotter. This program will plot from one to four graphs with one execution of the program. These graphs of the data have an *X*-axis length of 6 in and a *Y*-axis length of 4 in.

Input for the WTHR.GLDPLT program is:

Columns	*Item*	*Format*
Record 1: 1–2	Number of graphs to be done (4)	12
Record 2: 1–50	*Y*-axis label	5A6
Record 3: 1–60	*X*-axis label	6A6
Record 4:		
1–10	Beginning value of *Y*-axis	10.0

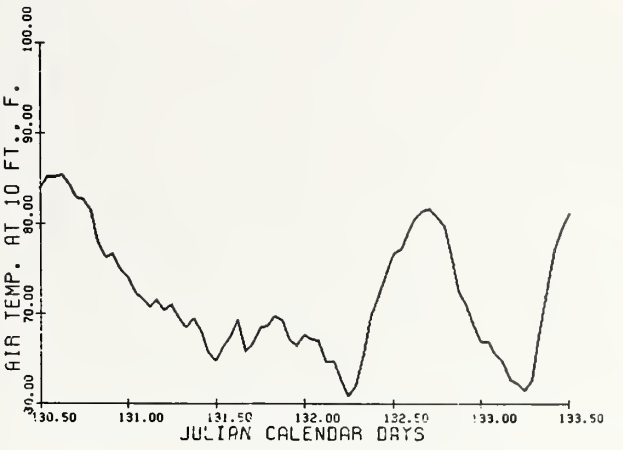

FIGURE 5.—Example of Gould-plotter output, air temperature.

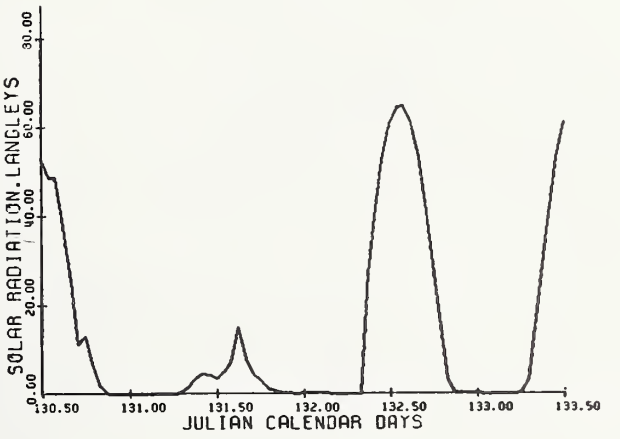

FIGURE 6.—Example of Gould-plotter output, solar radiation.

FIGURE 7.—Example of Gould-plotter output, wind speed.

11–20	Increment (every inch) of *Y*-axis	10.0

(*Y*-axis range goes to beginning value + increment value *4.)

Record 5:

1–10	Beginning value of *X*-axis	10.0
11–20	Increment (every inch) of *X*-axis	10.0

(*X*-axis range goes to beginning value + increment value *6.)

Record 6:

1–5	Number of curves to be plotted	I5
6–10	Number of points to be plotted	I5

Repeat following for each curve.

Record 7:

1–5	Point number at which curve label starts (points plotted per each curve are read in and called points 1, 2, 3, 4, . . .)	I5
6–17	Label for curve	2A6
18–22	Angle at which curve label is written (0°–360°)	F5.0

Record 8:

(Read in points to be plotted, one record per plotted point.)

1–15	*X*-value	F15.0
18–27	*Y*-value	F20.0

Repeat records 2–8 for each graph.

Examples of Gould-plotter output for a 3-day period are shown in figures 5–7.

RESULTS AND DISCUSSION

Certain points in the system require special emphasis. The need for a line power of 115 V a.c. can cause difficulties, especially in areas where service is frequently disrupted. When power is interrupted or drops suddenly, the electrical mechanism located in the data-acquisition system that acts as a clock and dating device returns to zero. Frequent checks must be made on instrumentation to avoid loss of data.

Certain field conditions are detrimental to the proper operation of this electrical equipment. Dust, prevalent in most agricultural situations, is especially damaging, and precautions must be taken to protect equipment. Because the dewpoint sensors are sensitive to dust, their reliability is less than adequate under the normal field conditions that we encountered.

Damage to the paper punch was sustained after a short period. Low-grade paper, which takes up moisture readily, may have caused the trouble. Only high-quality oil-impregnated paper should be used. Proper maintenance of the punch is required at regular intervals to assure proper operation. Repairs to the punch recorder are quite expensive and represent a disadvantage of this system.

Although the system is automatic, it is not a "set and forget" operation. Daily checks and maintenance must be performed by trained personnel. This system does not necessarily require the support of a trained electronics technician. Such support is difficult to obtain at many research locations and must be considered in planning any type of automatic data-collection effort. Periods of as long as 4 months of continuous operation without equipment problems have been experienced.

Overlooking the few shortcomings and the initial expense, we feel that the data-collection system described here is most valuable to ecological research programs. The future progress of agricultural science will require increased reliance of instrumentation in both biological and physical-data collection.

ACKNOWLEDGMENTS

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